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# A Systematic Mapping Study of HCI Practice Research

## Abstract

Human Computer Interaction (HCI) practice has emerged as a research domain in the HCI field and is growing. The need to transfer HCI practices to the industry began significantly with the works of Nielsen on usability engineering. To date, methods, and techniques for designing, evaluating and implementing interactive systems for human use have continued to emerge. It is, therefore, justified to conduct a systematic mapping study to determine the landscape of HCI practice research. A Systematic Mapping Study method was used to map 142 studies according to research type, topic, and contribution. These were then analyzed to determine an overview of HCI practice research. The objective was to analyze studies on HCI practice and present prominent issues that characterize the HCI practice research landscape. Secondly, to identify pressing challenges regarding HCI practices in software/systems development companies. The results show that HCI practice research has steadily increased since 2012. The majority of the studies explored focused on evaluation research that largely contributed to evaluation methods or processes. Most of the studies were on design tools and techniques, design methods and contexts, design work and organizational culture, and collaboration and team communication. Interviews, case studies, and survey methods have been prominently used as research methods. HCI techniques are mostly used during the initial phase of development, and during evaluation. HCI practice challenges in companies are mostly process-related and on performance of usability and UX activities. The major challenge seems to be to find a way to collect and incorporate user feedback in a timely manner, especially in agile processes. There are areas identified in this study as needing more research.

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## 1. Introduction

Human Computer Interaction (HCI) practice has emerged as a research domain in the field of Human-Computer Interaction and is growing. However, the research landscape in HCI practice is still not so clear. Furthermore, it is well documented in the existing literature that there are low uptakes of HCI practices in software development companies.

Combinations of methods such as field studies are used in practice research. Practice research can be practice-based research in which the new knowledge results in creating an artifact, or practice-led research in which new understandings about practice are achieved (Candy, 2006). HCI practice research tends to be both practice-based and practice-led. Vermeeren and Cockton (2013) used the Rogers' theory of innovation diffusion to propose how new HCI methods could be transferred successfully to work practice. Ogunyemi, Lamas, Adagunodo, and Rosa (2015) investigated the state of usability and user experience practices in the Nigerian software industry and found that the level of HCI awareness is low because very few Nigerian universities that offer HCI courses have elementary focus on HCI. It was also reported that a lack of distinction between users and customers existed in some companies. Similarly, Ardito, Buono, Caivano, Costabile, and Lanzilotti (2014) investigated the state of user experience (UX) practice in Italian software companies and found companies either still ignore usability and UX aspects in projects or merely conduct these practices on a low scale. Chilana, Ko, Wobbrock, Grossman, and Fitzmaurice (2011) investigated post-deployment usability activities and the state of user-centred design practice among 333 full time usability professionals and consultants and found that usability professionals are not being so

much involved post-deployment usability activities compared to other user-centered development phases. In another study, Chilana, Ko, and Wobbrock (2015) found the user-centred design method is disconnected from wide focus on the stakeholders because of its sole focus on the user, and therefore, proposed the adoption-centred design method. The rationale is that users are not usually the buyers of the product. This is especially so for non-consumer products.

HCI practice began to emerge as a necessity for development companies with the efforts of Nielsen on usability engineering (Nielsen, 1993). There was a need to transfer HCI practice to industry. Nielsen argued that since 48% of coding effort is used for user interface design (Myers & Rosson, 1992), it should be proportionally so, that the usability of user interfaces is prioritized. Shortly after Nielsen's introduction of usability engineering to development companies, a vision by Winograd (1997) suggested that computing as a discipline would shift to interaction due to the need to focus on people rather than machinery. Winograd (1997) foresaw the emergence of methods, skills, and techniques because of this focus on people. Since then, new design methods, techniques, and concepts have continued to emerge in the field of HCI, and interaction design is becoming a core focus for designers and companies.

One of the prominent design approaches in HCI is user-centred design (UCD). The UCD approach was first mentioned by Donald Norman and UCD began to gain prominence after Norman jointly authored the book "User-Centered System Design: New Perspectives on Human-Computer Interaction" with Stephen Draper in 1986 (Norman & Draper, 1986). User-centred design is a process design approach, and has been successfully researched and integrated at least to agile processes such as SCRUM and Kanban (See e.g. (Law & Lárusdóttir, 2015; Maguire, 2013; Sy, 2007)).

One important technique of the human-centred design<sup>1</sup> approach is design thinking, and has been popularised by IDEO and IBM. Design thinking is a design technique whose goal is to solve a specific problem by bringing different stakeholders on board. According to Rosenberg (2014) design thinking is a "creative problem-solving approach rooted in a model of human empathy, brainstorming methods, prototyping, and iteration" (p.75). Brown (2009) explained that design thinking is human-centred because of the balance it establishes regarding users, technology, and business' perspectives. Zimmerman, Forlizzi, and Evenson (2007) observed that design thinking is rarely defined and this can be seen in existing literature where some authors merely mention the technique without describing the essence of its use or applicability. For this reason, Zimmerman, Forlizzi, and Evenson (2007) define design thinking as:

"The application of a design process that involves grounding—investigation to gain multiple perspectives on a problem; ideation—generation of many possible different solutions; iteration—cyclical process of refining concept with increasing fidelity; and reflection" (p.494).

From this definition it can be seen that design thinking applies a design process that begins with establishing a problem, then continues by ideating, iterating, and reflecting. Design thinking has also been viewed as an approach that firms could use to innovate and

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<sup>1</sup> User-centred design and human-centred design are used interchangeably in the existing HCI literature.

gain competitive edge (Brown, 2008; D'Ippolito, 2014; Liem & Sanders, 2011). In particular Brown (2008) stated that the goal of design thinking is disruptive innovation for gaining competitive edge in the global market. People other than designers can conduct design thinking ((Brown, 2008) cited in D'Ippolito (2014)). Furthermore, Rosenberg (2014) believes design thinking can be viewed “as a philosophy, a methodology, and a value-creation model.” Nevertheless, Liem and Sanders (2011) noted that the design-led perspective of design thinking does not place value on the end-users as a stakeholder in the early front end of the process unlike the co-creation perspective that “puts the tools and methods of design thinking into the hands of the people who will be the future end-users (and the other stakeholders) early in the front end of the product development process” (p.113). In the same vein, Zoltowski (2010) argued that understanding the people being affected by the design is a crucial aspect of design thinking. For this reason, McGinley and Macredie (2011) submit that:

“When access to diverse user groups is unavailable, information about the groups has to be available instead – and it has to be in a format that is accessible and is perceived as having value by designers” (p.5).

A systematic mapping study produces a layout of research types. The results are obtained by categorization and the report generates a visual summary, which is the map of the results. The systematic mapping study method has been employed to provide a good overview of a research domain (Petersen, Feldt, Mujtaba, & Mattsson, 2008) and supports undertaking software engineering-related research needs (Kitchenham & Charters, 2007); thus, a systematic mapping study is selected as the most suitable way to harness the structure of research of HCI practice in a systematic way. One of the major differences between a systematic review and systematic mapping study is that unlike systematic reviews, systematic maps do not need assessment of quality of included papers (Petersen, Vakkalanka, & Kuzniarz, 2015). Therefore, this study would not assess the quality of the included papers.

This study aims to explore existing studies on HCI practice and produce a systematic map that shows an indication of what methods and techniques have been used and to what extent based on a carefully identified sample from the literature. There is an increase in recognition of HCI practices in software development companies and HCI influences several software engineering (SE) processes today (Ferre & Moreno, 2004). The findings of the study are beneficial to HCI researchers aiming to promote an HCI related approach in companies, as well as novice HCI researchers who need to situate themselves into HCI practice research. The outcomes provide some implications for research and practice. For HCI practice researchers, the HCI practice research landscape can be perceived more clearly, have insight to choose appropriate research methods for research works, be made aware of related works, and channel a better course for future research. HCI and software practitioners can benefit for example, from the taxonomy of HCI design techniques, and methods, which was carefully structured into three phases that would fit in the entire development lifecycle. Practitioners are also equipped with knowledge of the taxonomy and could learn more about these HCI approaches.

This paper is organized as follows. In the next section we provide a brief theoretical background to our study. In section 3 we describe our research method. In section 4, we present our classification scheme. Next we present the results and in section 6 we discuss the results, and provide implications for research and practice. Finally, we conclude the work and present directions for future work.

## 2. Background

There still appears to be a lack of coordination in HCI practices of how techniques and methods are being applied to software development processes and what challenges are being experienced. The term ‘HCI practice’ has been used loosely in many of the previous research works and there appears to be no clear understanding of what HCI practice actually entails. In order to articulate our thoughts, we would offer a definition of *HCI practice*. The vast amount of existing papers on HCI practice have described approaches used to conduct design, evaluation, and implementation of interactive systems people would use. We would, therefore, describe HCI practice as the application of HCI concepts, HCI techniques or methods to the process of analyzing, designing, evaluating and implementing interactive systems for human use. In this section, we situate the reader by providing an overview of HCI practice, taking a closer look at concepts, techniques or methods for HCI, which are core to its practice. We also present related studies and provide a justification for the need for a systematic mapping study such as ours.

### 2.1. HCI concepts, techniques or methods

We define an HCI concept as an abstract or generic idea derived and inferred from specific situations. The essence of using HCI concepts is to give meaning to design and cause a desired action to be produced. HCI concepts are becoming a bedrock of knowledge to assist practitioners in software development processes because HCI concepts focus on the user while designing interactive systems (Sousa & Furtado, 2003). Usability is an important concept in HCI (Rex Hartson, 1998; Rozanski & Haake, 2003; Zapata, 2015). It has been observed that the majority of software engineers are not trained in HCI and they possess little or no knowledge of how to apply HCI concepts in their technical activities (Bruun & Stage, 2012; Ludi, 2003). This view was earlier corroborated by Walenstein (2003) when he noted that creating awareness of HCI concepts and meanings for software engineering professionals is difficult due to educational differences. A recent study also corroborates the fact that HCI knowledge should be promoted among software developers (Øvad & Larsen, 2016). In their work, Sousa and Furtado (2003) presented a workflow called ‘RUPi’, which is based on four concepts; that is, human factors, guidelines, user interface for all, model-based UI generation. The study further shows how the four concepts could help to perform activities leading to production of artifacts that consider human factors, usability requirements, accessibility and acceptability, usability evaluation, and graphical scenarios generation when developing interactive systems for human use. Although HCI concepts are useful for designing interactive systems, not all are fitting to industrial practice. A notable example was provided in the work by Sener and Wormald (2008) in which 11 novel concepts had to be created for the purpose of form creation. The reason for creating new concepts was to react to the challenges expressed by industrial designers. It was reported that industrial designers could not apply Computer-Aided Design (CAD) to the design of industrial forms. A concept could only have excellent properties if those properties are implementable (Hudson & Mankoff, 2014). One of the concepts, which are central to HCI design, is that of value. Values are a block of emotional attributes anticipated by the system’s stakeholders, meant to drive system development. Values do not necessarily focus on sales and profit, but also for a personal, political, cultural, organizational or religious purpose, depending on what is deemed valued by a

stakeholder of a system (Cockton, 2004). To date, the development of interactive systems by software development companies is being limited by a lack of consideration of human values. Usability is perhaps not the only important consideration for the development of interactive systems, other values such as products' accessibility, affordability, enjoyability, sustainability, noticeability, appropriateness, among others have over the years become very important. Today's interactive systems have gone beyond usability and usability has been sufficiently researched in the HCI community. Accessibility of interactive systems is considered important to support people with certain disabilities (Hudson & Mankoff, 2014). Laws and guidelines have been promoted to enforce accessibility in designs especially for web-based systems and accessibility design require more than informal evaluation, ad-hoc quality testing activities (Molina & Toval, 2009). Appropriation of a system to a given context based on particular needs is important when considering voluntary adoption (Hayes, 2014).

**HCI techniques or methods**, just like HCI concepts, are important knowledge blocks for practitioners. The field of HCI has for more than three decades focused on the design, evaluation and implementation of interactive systems for human use and has developed several techniques and methods, which can be applied to achieve the development of usable systems for people. To date, techniques or methods such as the think aloud protocol, personas, scenarios, wire frames, Wizard of Oz, software usability scales, card sorting, heuristic evaluation, participatory design, user-centred design, and human-centred design have been reported in the literature. However, there still appears to be a lack of coordination in HCI practices of how techniques or methods are being applied to software development processes and what challenges are being experienced. HCI techniques or HCI methods have similar meanings within the literature and are used interchangeably by HCI researchers.

**Personas, scenarios, storyboards, and visual brainstorming** were cited by Ferre and Medinilla (2007), as examples of HCI techniques. Ferre and Medinilla went ahead to stress that HCI techniques have to be dynamically applied for as long as approaches to interactive systems development continue to change. Similarly, Downey (2007) described five formative usability testing techniques namely; co-discovery, individual usability testing, cooperative usability testing, task-based focus groups, and group usability testing. Hochheiser and Lazar (2007) described participatory design, contextual inquiry, and paper prototypes also as HCI techniques. Bødker and Christiansen (2004) gave examples of paper mockups, and video prototyping as well as HCI techniques.

Nivala, Tiina Sarjakoski, and Sarjakoski (2007) described **user-centred design and usability engineering** as HCI methods. The authors, in particular, indicated that usability engineering is a term used for describing methods for making software usable and enumerated interviews, surveys, contextual inquiry, focus groups, brainstorming, as examples of usability engineering methods. Similarly, Majid, Noor, Adilah, and Adnan (2012) described user-centred design, usability engineering, and participatory design as HCI methods. The authors reiterate the fact that some researchers had used different terms such as approach, process, method, concept, and technique to refer to user-centred design, usability engineering, human-centred design, and participatory design. Similarly, Dighe and Joshi (2014), referring to previous works, described usability engineering, and human-centred design as HCI methods.



From the foregoing, we perceive ‘HCI techniques’ and ‘HCI methods’ as two congenial terms used interchangeably by HCI researchers. The focus has not really been on whether there should be a distinction between the two terms, but rather that researchers are prone to using the two terms to describe approaches for analyzing, designing and evaluating interactive systems; albeit some techniques or methods being low cost and fast to use and some not. Therefore, we do not want to distinguish between these two terms but believe they are being used interchangeably. Both a "technique" and a "method" are ways of doing things.

## *2.2. Related studies*

**Systematic review and mapping studies** have increased in recognition among scholars in HCI and SW engineering disciplines (Kitchenham & Charters, 2007). Salvador, Nakasone, and Pow-Sang (2014) conducted a systematic review study on usability techniques in agile methodologies. The aim of the study was to synthesize existing studies on usability techniques in agile methodologies and identify what is the scope of the current works on the discourse and what areas require attention for future research. The outcomes of the study indicate that complementary usability techniques are used with agile methodologies and evaluation is conducted at the implementation stage only. There is a huge risk considering the cost of fixing post-deployment usability issues. Evaluations are mainly in the form of case studies. Although the study by Salvador et al. (2014) provided useful insights regarding usability techniques, we also need to know what happens at the different phases of development where HCI approaches are being applied.

In their study, Fernandez, Insfran, and Abrahão (2011) examined 206 papers and found 39% of usability evaluation methods specifically targeted for web development. The study revealed that user testing is the method mostly used for evaluation. The study provided quality maps, which could be used to undertake research on usability evaluation methods for web application. However, just like the study by Salvador et al. (2014), the major difference with our aim is that the scope of Fernandez et al. (2011) is limited to evaluation of web applications.

Brhel, Meth, Maedche, and Werder (2015) conducted a systematic review of user-centred agile software development and the goal was to identify principles that constitute user-centred agile software development (UCASD). The study identified five broad principles for UCASD and these could be utilized in software development processes and practices. The five principles are perceived to be important for the design of useful and usable software. Three of the five principles are regarding the development process and they are: a) separate product discovery and product creation; b) iterative and incremental design and development; and c) parallel interwoven creation tracks. The remaining two principles are continuous stakeholder involvement, and artifact-mediated communication and are defined as practices for the principles of UCASD.

Bertholdo, Da Silva, De O. Melo, Kon, and Silveira (2014) examined existing literature on **agile and UCD methods** and observed there was a gap regarding the practice with agile UCD methods. Based on the identified gap, Bertholdo et al. (2014) proposed agile usability patterns for the early stages of UCD. The proposal is to foster practitioners’ understanding of the contexts of applying the agile usability patterns and to bring out the problems that can be experienced within varying contexts. The study by Bertholdo et al.

(2014) improved our understanding regarding contexts of applying UCD methods. However, being a review, there is still need for a more systematic approach and mapping studies regarding HCI practices. Similar to the work of Bertholdo et al. (2014), there was an indication that the context of use of a system is majorly overlooked. For that reason Mosqueira-Rey, Alonso-Ríos, and Moret-Bonillo (2009) proposed a usability taxonomy that describes context of use and relevant attributes in a more holistic manner. The major limitation of their study is that it lacked a systematic approach and, therefore, weak methodologically. In a survey and a closely related study, Bark, Følstad, and Gulliksen (2006) explored the use and usefulness of HCI methods among 179 HCI practitioners from the Nordic countries. The goals of the study were to understand which HCI methods HCI practitioners perceived as most useful in varying projects stages and to identify if ICT project types have any impact on HCI practitioners' perceptions. In the study, project phases were divided into start, mid, and end phases and 20 different HCI methods were grouped into these. HCI methods aimed at systems planning, analysis and specifications were grouped under the start phase, design was grouped under the mid phase, and evaluation was grouped under the end phase. Field studies and interviews were perceived as the most used methods in the start phase. User tests and rapid prototyping were perceived as the most used methods in the mid phase, while user testing followed by expert evaluation were rated the most used methods in the end phase. We argue that the contribution Bark et al. (2006) provided a lot of insights into HCI practices in software engineering processes and projects, albeit nothing is still known about the classification of HCI work practices and studies of this nature are to date, very scarce. There is a need to extend the scope of the work of Bark et al. (2006) by conducting a systematic mapping study to achieve a comprehensive understanding of HCI practice and guide future research.

Four out of the six related studies were based on usability evaluation and analysis. **Usability** is considered a central topic in HCI (Rex Hartson, 1998; Rozanski & Haake, 2003) and is gaining attention in the SE community (Mosqueira-Rey et al., 2009). All the six studies provide a good overview of usability practice in companies and reveal various methods and techniques that are in use and various stages in the lifecycle where these approaches are being used. It can only be expected that there are better approaches to design and development of interactive systems with these kinds of contributions.

### *2.3. The need for a systematic mapping study*

Although the definitions are clear regarding what constitutes aspects of HCI practices, the overarching concern is that HCI practices papers vary in terms of application (processes, users, organizations, projects) as well as purpose (description, prediction, prescription). Thus, we look closely at HCI practices from three perspectives:

1. Description of design concepts, techniques, or methods;
2. Analysis of design concepts, techniques, or methods in order to predict patterns of user behaviour and experience as a result of actual or anticipated interaction with systems;
3. Evaluation of design concepts, techniques, or methods in order to prescribe solutions to problems being encountered as a result of the application of these approaches to the development of interactive systems and the user experience.



We have taken these three perspectives from the ACM definition of human-computer interaction (Hewett et al., 1996). The core elements of the definition are design, evaluation, and implementation.

This study is important in order to foster our knowledge regarding HCI practices in software development companies. Considering the amount of research results produced in the field and the fact that there is still low awareness and knowledge of HCI in development companies, we need to know what characterizes HCI practices in companies and what challenges are being experienced. We as researchers require a clear focus regarding HCI practices in the industry for the ability to conceptualize these practices and set clear foundations of their structure and process.

**Table 1**

Systematic mapping study process adapted from Paternoster, Giardino, Unterkalmsteiner, Gorschek, and Abrahamsson (2014). Note that the underlying procedure has been adapted from Petersen et al. (2008)

Steps for the process	3.1 Define research questions	3.2 Search	3.3 Inclusion and exclusion of papers	3.4 Classification process	3.5 Extract data and map	3.6 Synthesize results
Outcomes	Study scope review	Search for all papers in relevant sources	Obtain relevant papers	Classify scheme	Produce systematic maps	Classify HCI practices and challenges

### 3. Method

*“If I have seen further than others, it is by standing upon the shoulders of giants”* – Sir Isaac Newton (1642 - 1727)<sup>2</sup>.

We have followed the guidelines described by Kitchenham and Charters (2007) as well as the systematic mapping procedure by Petersen et al. (2008) and Petersen et al. (2015) to conduct this systematic mapping study. We favored a systematic mapping study ahead of a systematic review study. Our desire is to explore HCI practice based on a carefully identified sample of studies from the literature. A systematic mapping study helps to derive a visual summary, and “a more coarse-grained overview” of research studies thereby providing a clear structure of a research domain (Petersen et al., 2008). Thus, we are inspired that a systematic mapping study would allow us to indicate what methods and techniques have been used and to what extent based on carefully identified sample from the literature.

#### 3.1. Research questions

The questions drawn in this study have been framed based on three components proposed by Kitchenham and Charters (2007) and adapted from Neto, MacHado, McGregor, De Almeida, and Meira (2011).

1. Population: peer-reviewed literature on HCI practices;

<sup>2</sup> Source: The Internet

2. Intervention: empirical studies on HCI practice, that is, concepts, techniques or methods, in relation to software development processes or projects;
3. Outcomes: Type and quantity of evidence relating to various HCI practices, in order to identify research trends in this domain.

Based on the three components therefore, and in order to address the broad aim of this study, the questions raised are presented in Table 2.

**Table 2**

Research questions and goals

Research Questions	Goals
RQ1. How are HCI practice papers distributed over the years and in what venues?	To determine the progression of HCI practice papers and where they can be majorly found.
RQ2. What types of papers are published in the topic areas and what type of evaluation and contribution do they offer?	To have a broad overview of what characterizes HCI practice in terms of research type, contribution, and topic focus.
RQ3. What research methods have been mostly applied in HCI practice researches?	To determine which research methods have been used mostly by researchers and understand whether or not a specific method could be more relevant than the others when conducting HCI practice research.
RQ4. What HCI techniques have been reported in the current literature regarding HCI practice and in what context of use?	To determine which techniques are mostly frequently used and the context of their use.
RQ5. In what development project areas have HCI practice been applied as documented in the existing literature?	To identify to which development kinds are HCI practice been commonly applied.
RQ6. What challenges have been reported in software development companies regarding HCI practices?	To identify pressing challenges regarding HCI practices in development companies that could be interesting for future research.

### 3.2. Literature Search

In line with the frame of components presented in Table 1, we searched digital libraries in order to identify our primary objectives. We explored combinations of various keywords in order to derive a search string. The core concepts of HCI practice are usability engineering and interaction design and the keywords presented as terms in Table 3 were derived from these two concepts. The keywords (terms) are associated with papers on HCI practice and not HCI practice on their own. The search string is simple and is presented in Table 3.

**Table 3**

Search strings

Concepts	Keywords
HCI Practice	usability*; human-centred design*; evaluation technique*; user-experience*; user-centred design*; hci practice*;
Development Process	agile software engineering*; software*; practitioner*; post-deployment evaluation*; software industry*; software process*; process*; practice*; method*; methodology*;

The keywords were from our research questions. Our search was conducted for literature up until 31 July 2016. Table 4 is the presentation of the digital sources on which we have conducted our search. The databases were selected because articles relating to HCI and SE are found in them. We also looked at previous systematic studies such as Inayat, Salwah, Marczak, Daneva, and Shamshirband (2015) and Paternoster et al. (Paternoster et al., 2014) to draw our inspiration regarding sources to look for HCI and SE articles.

**Table 4**

Papers retrieved from selected digital libraries

S/N	Digital Library/Database	# Papers
	ACM	604
	IEEE Xplore	10
	Springer	742
	ScienceDirect	125
	Taylor and Francis	651
	Wiley Online	236
	Scopus	16
	Total	2384

### 3.3. Inclusion and exclusion of papers

The criteria set for including a paper are that such paper is peer-reviewed, empirical, written in English, published between 2000 and 2016 and must show a clear connection between certain HCI concept, or technique, or methods being applied or integrated to software/system development processes or projects in practice. Non-empirical papers such as experience papers, opinion papers, philosophical papers, and solution papers are also included considering that the task is to map HCI practice papers. The rationale for selecting studies published since 2000 is because the discourse on integrating HCI methods to software engineering processes began prominently around early 2000s (John, Kazman, Chen, & Marcus, 2004; Ogunyemi & Lamas, 2014) and it feels appropriate to conduct a search beginning at this period. Theoretical papers proposing a concept, technique or method that stems from empirical investigation(s) were also considered. We included only the most recent version of papers that reported the same study.

The criteria for excluding a paper are as follows:

- Studies not written in English;

- Studies not directly linked to software development processes or projects;
- Studies based on tutorials, panel discussions;
- Short papers (< 4 pages);
- Newsletters, magazine articles, personal blogs;
- Studies that are relevant but could not be accessed.

Table 5 is our screening process. A similar approach was used by Brhel et al. (2015). The screening process included five stages. We applied the inclusion and exclusion during each phase. There were some other papers that report on the use of HCI methods and had to be removed. In many cases, this set of papers either does not meet our requirement for page limit, or are not linked to software development processes or projects. There are some papers on software development that are not linked to HCI and also have to be excluded. Some of the papers that do not meet our page limit requirement are workshop and panel papers. In a few cases, some relevant papers were not accessible.

**Table 5**

Screening process for finding relevant papers (Adapted from Dybå and Dingsøyr 2008))

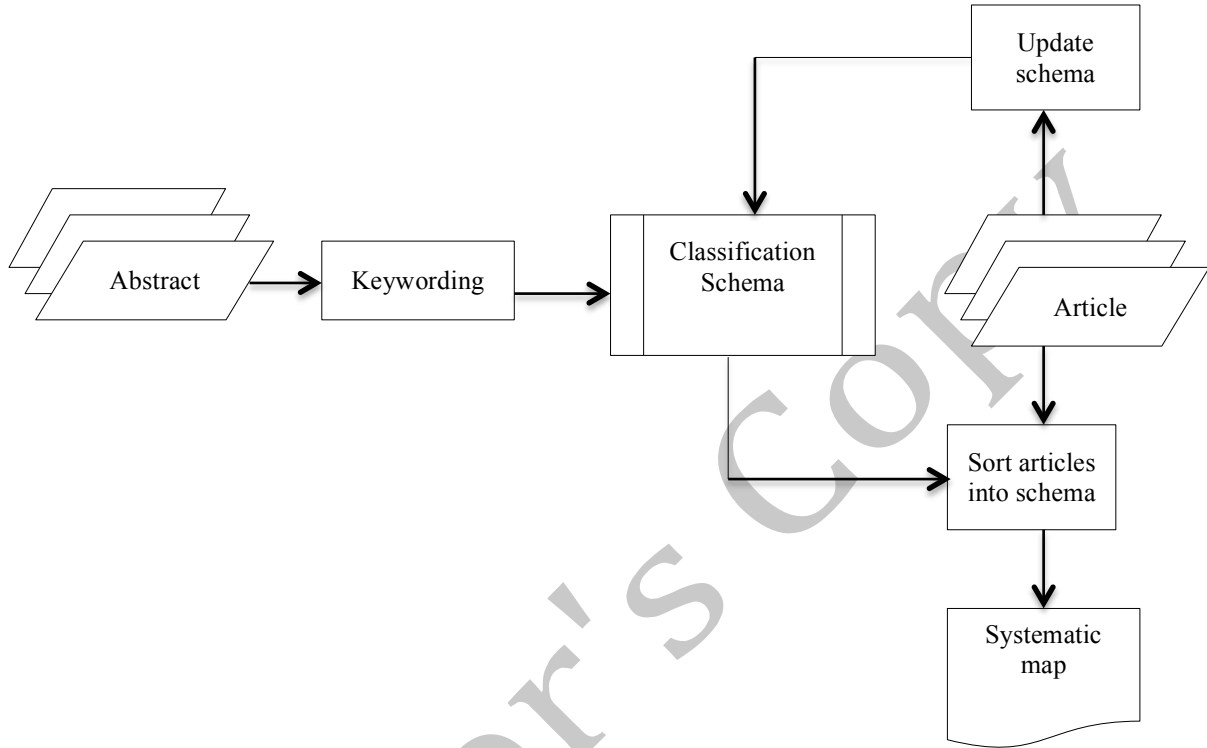
Phase	Process	Result
I	Automatic search in digital libraries	2384
II a	Screen by paper titles	340
II b	Manual search in book of proceedings	43
III	Exclude duplicates	332
IV	Screen by paper abstracts	167
V	Screen by reading whole content of primary papers	142

We found 2384 papers automatically by searching digital libraries using the terms in Table 1. The results of the search are in Table 4. In the second phase, we screened the results of the automatic search by reading the papers' titles and reduced the list to 340 potentially relevant papers. Most of the articles found and discarded during this stage were editorials, panels, tutorials, special issues, and summaries. In addition to the second phase efforts, we manually searched proceedings of conferences such as Agile, INTERACT, CHI, HCII, NordiCHI, HCSE, ICSE, and found 43 relevant papers. Therefore, we added the 43 papers to the 340 potentially relevant papers and screened further by checking for duplicates. The list reduced to 332 potentially relevant papers after excluding duplicated papers. In the fourth phase we read the paper abstracts and eventually discarded 165 papers, bringing the number of potentially relevant papers to 167. In the fifth and final phase each paper was fully read and the finally included papers were reduced to 142 and analyzed further.

### 3.4. Classification process

The process described in Fig. 1 was followed in order to build the classification scheme of the primary studies. The rationale for identifying keywords from papers is to be able to build a valid classification scheme from the included primary studies (Petersen et al., 2008). We read the abstracts of the included papers and assigned keywords and concepts that clearly reveal the contribution of the articles. During this process, we also identified

the context of each paper. We categorized the keywords and continued to update our schema. We refined the schema iteratively as we obtained new data. Eventually, we came up with the final classification schema. Furthermore, we used the schema to analyze the results presented in Section 5.



**Fig. 1.** Classification scheme building process (Adapted from Petersen et al. (2008)).

### 3.5. Extraction of data

We created a spreadsheet and extracted the following data, based on the classification scheme we have drawn, and following the methodology of similar studies such as (Da Mota Silveira Neto et al., 2011; Paternoster et al., 2014; Wendler, 2012):

- Title of the paper;
- Publication year;
- Research methodology;
- Focus of the paper (in order to form themes of topics);
- HCI practice investigated;
- Software development lifecycle covered;
- Specific issue addressed in paper;
- Context (whether focused on projects or company process);
- Keywords.

We read abstracts as well as the full papers being guided by the process we have defined for extracting data.

### 3.6. Synthesis

Data synthesis was done through automatic and manual processes. With automatic process, we used the MS Excel tool to collate data into a spreadsheet and thereafter perform some statistical analysis, which came up with relevant charts. In terms of the manual process, we performed the classification by topic ourselves by theming the keywords from the papers and categorizing them. Furthermore we repeated the process iteratively and refined and eventually arrived at the classification presented in this study.

## 4. Classification scheme

We followed the concept of keywording of abstracts described by Petersen et al. (2008). From the primary studies, we derived themes from the keywording process into topics as can be seen in Table 6 (a). Other aspects included in Table 6 are the classifications into research types (b), and contribution (c). Both classifications into research types and contributions were adapted as indicated in Table 6 (b), (c). The scheme presented in Table 6 is the basis for our systematic map presented in Figure 3.

**Table 6**

Classification scheme.

Category	Descriptions
<i>(a) Topic Facet</i>	
Design evaluation and integration to software processes	Evaluation kinds and approaches to integration of HCI methods and techniques to SE processes.
Design methods and contexts	Application of design methods in practice. Exploring the different ways design methods are applied in contexts, effectiveness of design techniques in use. Nature of practice and contexts in which teams work together. Approaches by which design methods could be improved.
Design innovations	New ideas, concepts or ways for enhancing design and development of interactive systems.
Design-driven software methodologies	Integration of HCI methods and techniques to SW development methodologies.
Domain and knowledge	Exploring how design work is being done when there is little or no expertise required. Ways of mitigating shortage of skills in practice in order to perform specific work tasks.
Design tools and techniques	New or existing tools and techniques for applying user research methods. Tools for evaluating software usability.
User research methods	Existing or proposed design methods for conducting user research.
Post-deployment activities and software maintenance	Feedback and other activities carried out after deployment of software for use.
Design work and organizational culture	Pre-deployment or implementation activities and organizational issues such as readiness.
Cross-cultural design	Methods and techniques for collecting user data across cultures.
Software process improvement	Assessment of software processes using maturity models and allied tools.

Design-driven software architecture	Exploring the interplay between design approaches and software architecture.
Collaboration and team communication	Exploring issues in, and ways of improving team communication and collaborations in organizations, or ways of enhancing end-user participation due to certain constraints such as illiteracy, disability or lack of willingness of the end-user.
<i>(b) Research Facet (adapted from Wieringa, Maiden, Mead, and Rolland (2006))</i>	
Validation Research	Paper reports a study conducted in order to validate a proposed solution before its implementation in practice. Study uses relevant research methods such as experimentation, prototyping, modeling, simulation, etc.
Evaluation Research	Paper explicitly describes a problem in practice; study uses appropriate research methods to conduct the investigation. The paper builds on related studies and offers a significant contribution how the situation could be improved.
Solution Proposal	Paper proposes new ideas, techniques, or methods and tries to justify their relevance. The idea, techniques, or method might be novel or aims at improving the existing ones. In order to establish the relevance of the proposed solution, paper might include a description of a small-scale study.
Philosophical Papers	Paper presents new approach of conducting investigation into a known phenomenon. The approach could be a conceptual framework, or model, etc.
Opinion Papers	Paper expresses the personal opinion of the author about an issue, usually on <i>what</i> and <i>why</i> of such issue, or <i>how</i> things could be done.
Experience Papers	Paper emanates from personal experience of the author. The paper enumerates lessons learned from the experience of the author, usually an industry practitioner, or a researcher who have used a tool. The report is without a description of research methods.
<i>(c) Contribution Facet (adapted from Mujtaba, Petersen, Feldt, &amp; Mattsson (2008))</i>	
Process	Activities or actions and their corresponding work flow.
Tool	Tools developed to support work activities, for example, software tools to support design activities.
Method	Set of rules or ways things should be carried out.
Model	Connotation of real world using semantics and notations, representing something on a smaller scale, hypothetical description of a process, e.g. UML, simulation, maturity models, etc.
Metric	Standards used for measurements.

## 5. Results

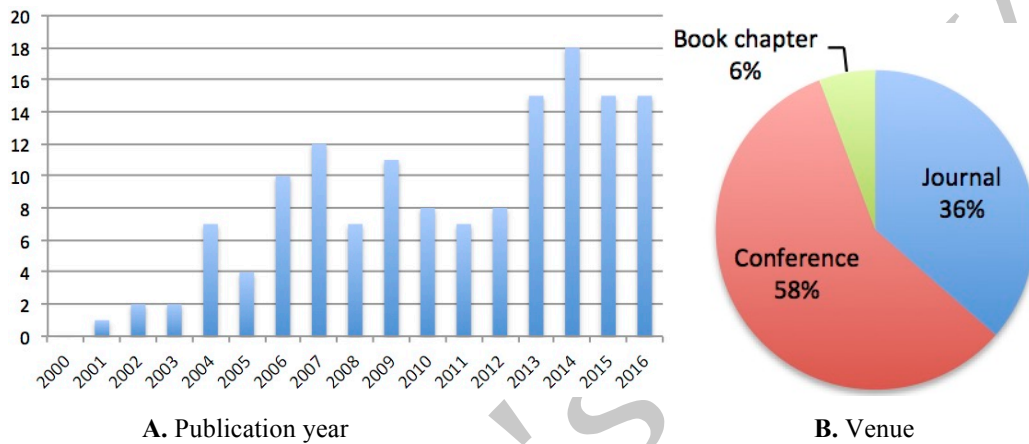
We present the results obtained from the analysis of the 142 primary studies.

### 5.1. HCI paper distribution and venues

The distribution of the 142 papers included is shown in Figure 2. It is understood that HCI practice research began to gain preeminence from 2003. During this period, deliberate efforts were made to bridge the gap between the HCI and software engineering fields. For example, a workshop was held in 2003 and the theme was “Closing the Gap: Software Engineering and Human-Computer Interaction” (Harning & Vanderdonckt, 2003). The overarching concern at that time was to successfully integrate HCI methods into software engineering processes. As can be seen also in Figure 2B, majority of HCI practice papers have been shared through conferences. Precisely, 82 or 58% of the



included papers were published in conference proceedings. There has been a steady increase in number of works produced on HCI practice from 2011. Apart from usability, which has been dominating the discourse, other issues that emerged include accessibility, user experience, and inclusiveness. These issues were found in papers such as SM112 published in 2009 and SM91 published in 2013 respectively. User experience is a dominating topic too as can be seen in many of the included papers. Since we stopped our search in July 2016, it is possible there could be more interesting papers produced from 2016 to date. This suggests there is a need for constant updating of mapping of HCI practice research papers.



**Fig. 2.** Publication year and venue of primary papers

### 5.2. HCI paper topic, evaluation, and contribution types

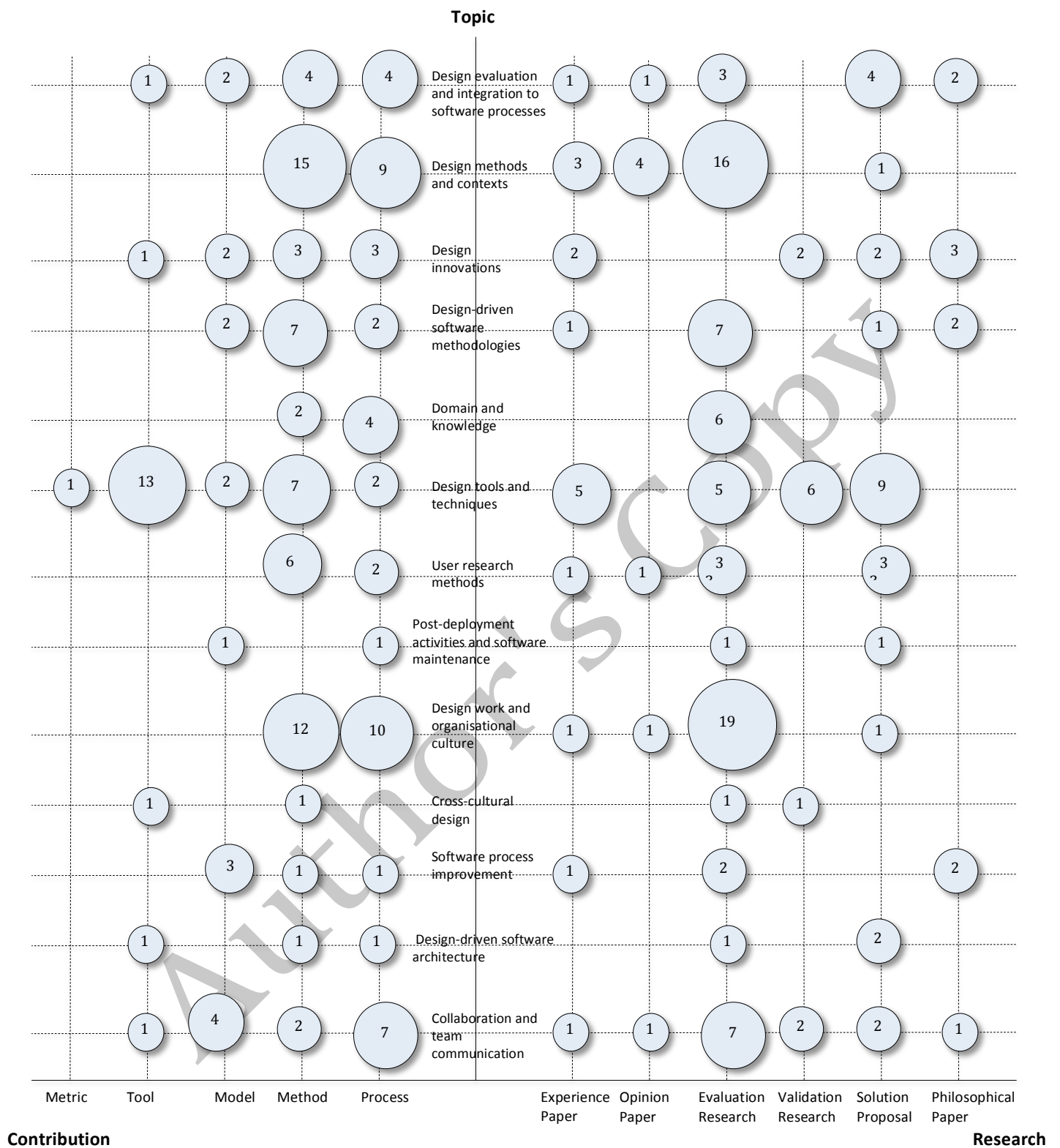
Figure 3 is the overview of potential gaps in HCI practice research. We retrieved keywords describing the topic being addressed by each study as well as its type of research and contribution from a paper's abstract and author-defined keywords. Sometimes, we read the full paper if the contribution, research type and the topic being addressed cannot be well established and clear from the abstracts.

The systematic map is presented with three dimensional bubble charts on x-y coordinates showing the areas of intersections (Petersen et al., 2008). The map shows an overview of the 142 primary studies we have chosen to be a representation of HCI practice. For example, in the dimension of topic, there are not many studies on post deployment activities and software maintenance (2 papers or 1%), cross-cultural design (2 papers or 1%), and design-driven software architecture (3 papers or 2%). However, 22 papers or 16% of the papers were on design work and organisational culture, design tools and techniques (25 papers or 18%), design methods and contexts (24 papers or 17%), collaboration and team communication (14 papers or 10%), and software process improvement (5 papers or 4%) and appear to be the dominating topics among the included papers. In particular, software process improvement has emerged to be a topic in the HCI practice domain since maturity models began to gain recognition in HCI practice research. Similarly, in the research type dimension, there are 11 papers on validation research (8%), 10 philosophical papers (7%), and 8 opinion papers (6%) among others

while the bulk of the papers are on evaluation research (73 papers or 51%). In terms of contribution, there were 18 papers on tool (13%), 16 papers on model (11%) and just one paper on metric (1%). The bulk of the papers were method-based (61 papers or 43%) and process-based (46 papers or 32%).

In terms of mapping the results in Figure 3, it can be seen that almost all of the topics cut across different research types and offer different kinds of contributions. For example, collaboration and team communication as a topic was published as an experience paper, opinion paper, evaluation research paper, validation research paper, solution proposal paper and philosophical paper and at the same time offer contributions as tool, model, method, and process support. Thus, the topics appear not to be context-specific.

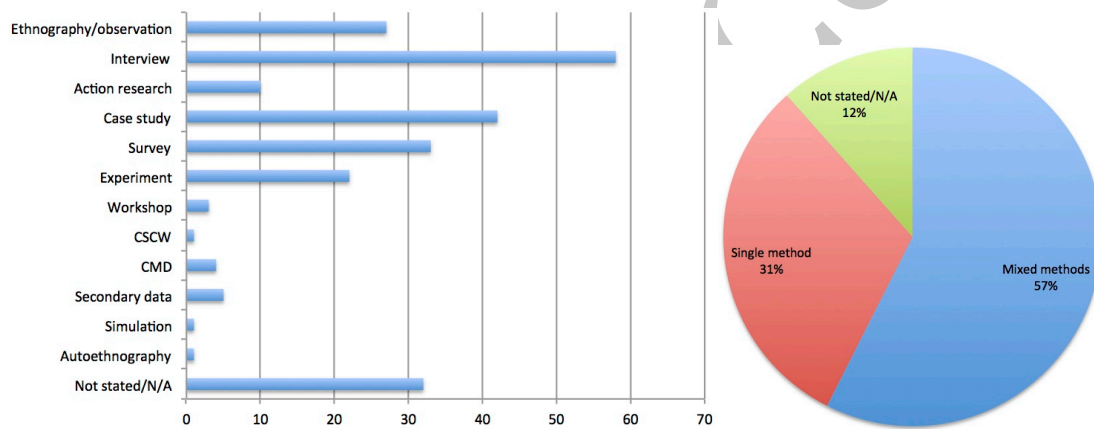
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**Fig. 3.** Systematic map – Topic, research type, and contribution

### 5.3. Methods used to conduct HCI practice research

The analysis with respect to RQ3 shows a variety of methods has been employed in conducting HCI practice research. One hundred and fourteen or 80% of the included articles were empirical and 28 papers were not empirical. These non-empirical papers include 6 experience papers, 8 opinion papers, 4 philosophical papers, and 10 solution proposal papers. However, there were 14 solution proposal papers that were empirical. These solution proposal papers employed a variety of methods such as experiment, case study, CMD, and survey among others. For example, SM04 (Kaasinen et al., 2015) proposed five approaches for acquiring insights for UX goal setting and conducted interviews in the context of an industrial system. SM08 proposed a method (Informal Cognitive Walkthrough) and conducted a laboratory experiment. Similarly, SM09 proposed a combination of two discount usability methods (RITE+Krug) and used the experiment method. SM11 while aiming to resolve the additional problems that arise after collecting user feedback when developing mobile applications proposed the CAFÉ (Context-Aware User Feedback) framework and was evaluated using experiment and interview methods.



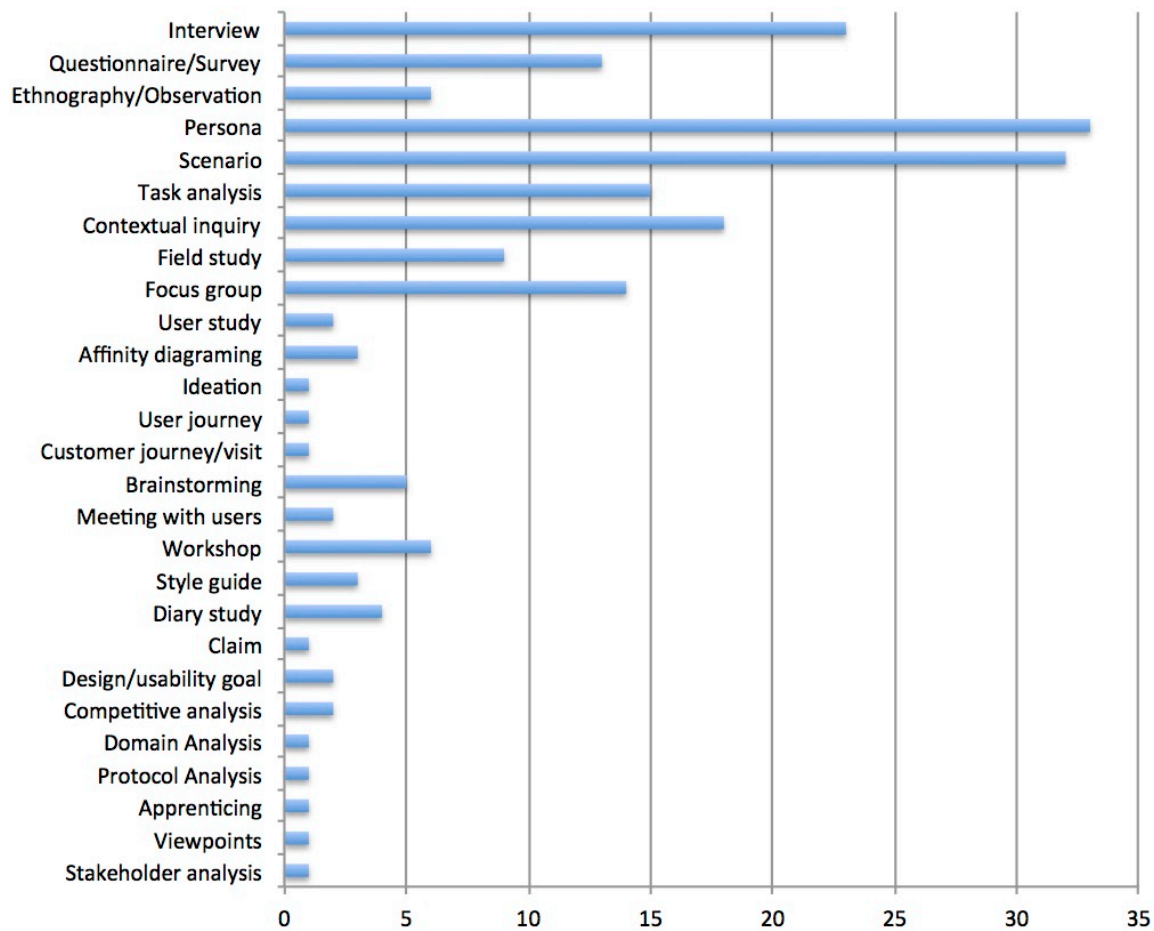
**Fig. 4.** (A) Research methods used in primary studies, (B) Proportion of methods used singularly to mixed methods

There were also 5 empirical philosophical papers and they used methods such as case study, survey, experiment, observation, and interview. For example, SM14 argue for software engineering to promote social change and describe a software development management framework that integrates action research, participatory design, and agile development to support the needs emanating from social software projects. SM14 carried out a social innovation case study. Figure 4 (A) shows that the interview method has been widely applied by almost half of the primary studies. Fifty-eight papers or 41% used the interview method. In Figure 4 (B), we can see that the proportion of studies that used combined methods (mixed) (57%) is greater than those, which used singular methods (31%).

### 5.4. HCI techniques and context of use

Figures 5(A-C) are indication of HCI techniques that were reported by the primary studies. The figures are divided into three phases and these were adapted from Bark et al.

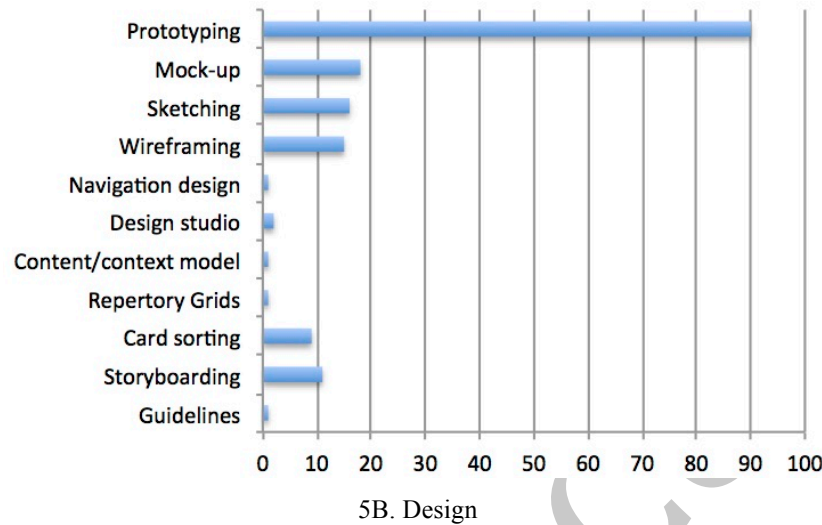
(2006). The phases are analysis and requirement, design, and evaluation. These phases are also described as the start, mid, and end phases.



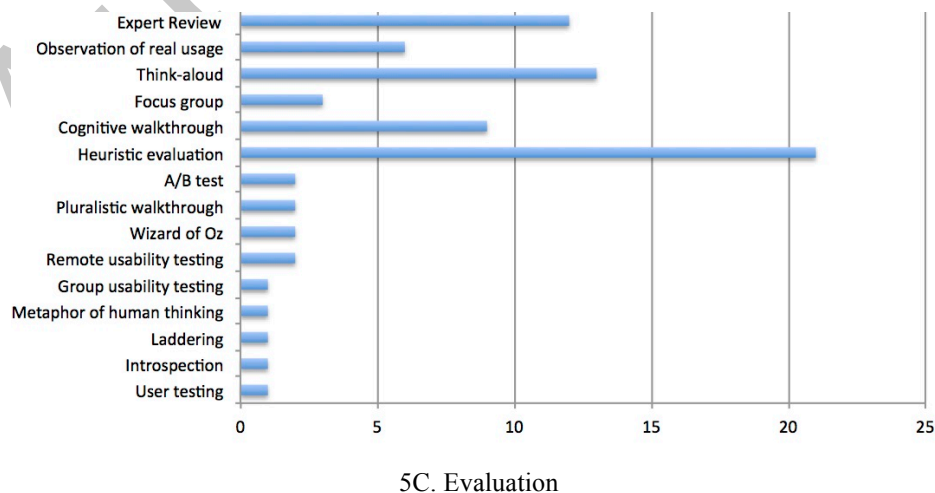
5A. Analysis and Requirement

**Start Phase.** Figure 5(A) suggests that regarding the start phase of development projects, techniques such as persona (33 papers), scenario (32 papers), interview (23 papers), contextual inquiry (19 papers), task analysis (15 papers), and focus group (14 papers) are mostly used. For example, personas and scenarios have been applied in varying project contexts. In the study by SM02, personas were used in the context of a management system implementation. SM10 used personas in the context of a mobile application design and evaluation due to missing usability requirements. SM32 also describe the use of personas in the context of an in-house development project that integrates usability and health issues. SM44 used personas and scenarios techniques in the context of implementing a game development project for children and the motivation was to increase the overall user experience. There were techniques such as claims, competitive analysis, domain analysis, and viewpoints that are interesting but not commonly reported unlike persona, scenario, interview, and contextual inquiry. For example, claims have been defined as a “means of expressing HCI knowledge that is associated with a specific artifact and usage context” (Sutcliffe & Carroll, 1999, p. 213). According to Sutcliffe and Carroll (1999) claims are “created in the task-artifact cycle of interactive design and

evaluation” (p.213). Techniques such as contextual inquiry and interview might be similar as both tend to be used to elicit certain knowledge or information directly from stakeholders such as users. Contextual inquiry and field study are also similar in the way that both are conducted in the context of the user.



**Mid-Phase.** Regarding the mid phase, it appears that prototyping (90 papers), sketching (16 papers), mock-up (18 papers), wireframing (15 papers), and storyboarding (11 papers) techniques are mostly used in designing software. The results are shown in Figure 5(B). These techniques have also been used in different development contexts. For example prototyping has been used in the contexts of designing game development software (SM44, SM96, SM100), mobile application (SM45, SM51, SM56, SM65, SM68, SM88, SM89, SM124, SM131), web application (SM50, SM60, SM69, SM80, SM88, SM89, SM107, SM112, SM132), information systems, SM70), educational software (SM91), ambient intelligence system (SM120), and generally product development (e.g. SM48, SM59, SM64, SM66, SM82, SM83, SM93, SM108, and SM116). Meanwhile wireframes and mock-ups are some forms of low fidelity prototypes.



**Fig. 5.** HCI Techniques found in studies

**End-Phase.** Regarding the end phase, it appears that heuristic evaluation (21 papers), think aloud (13 papers), expert review (12 papers), and cognitive walkthrough (9 papers) techniques are mostly used in software projects evaluation. It can be noted that heuristic evaluation, cognitive walkthrough and expert review are all review-based methods that don't involve users. The major difference between cognitive walkthrough and pluralistic walkthrough is that unlike the former the latter brings together representative users, the system designers, and a usability expert for the walkthrough session.

#### *5.5. HCI practice research application areas – (Development Areas)*

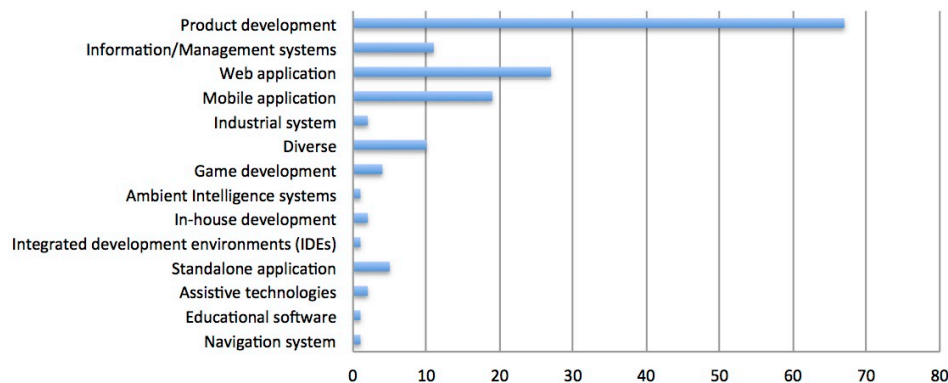
The results in Figure 6 indicate that HCI practice has been widely applied. The mostly applied area is in product development. As can be seen in Figure 6, there are 67 papers on product developments. The results, however, do not suggest tying particular HCI techniques to particular areas of applying HCI practice. Rather the results only give an insight that HCI practice is being conducted in several development domains. Furthermore, some papers are not about developing a specific product, but meta-papers such as survey studies. As an illustration, there were 90 papers (Figure 5B) that reported the use of prototyping techniques and of this, 40 papers are on product development. Similarly, other studies that reported the use of prototyping include 14 papers on web application, 11 papers on mobile application, 1 paper on ambient intelligent system, 4 papers on game development, 1 paper on educational software, 1 paper on assistive technologies, 8 papers on diverse development, 7 papers on information/management systems, 2 papers on in-house development, and 1 paper on industrial system development.

Product development is more or less associated with commercial products and many of the studies indicate differing areas regarding HCI practice in product development. For example, SM27 examined usability capability maturity assessment of a product development organization. SM29 argued that user involvement is interwoven with organisational culture in product development and suggests cultural analysis of product development organisations. SM39 explored the role of usability maturity models in integration of UCD and agile processes. Similarly SM41 examined the state of integration of usability/UCD to agile methods. SM93 and SM94 reported how their organisations adapted to Agile UX/UCD. In particular, SM93 reveal moving from waterfall to Agile UCD was a learning curve for their organisation. Similarly, SM98 described 5 myths associated with Agile UX practice in product development organisations. The myths are: (1) there is only one way to “do” Agile UX; (2) one cannot conduct user research; (3) no “upfront” design is permitted; (4) UX deliverables or documentation should NOT be created (or MUST be created); and (5) one doesn’t need to have any agile training. SM99 shared how UX practice is being conducted at Google. The paper indicates that a focus on user is crucial for the success of a product development organisation. SM48 reveals that users responsibilities in SCRUM projects are not clear, and SM55 describes how usability evaluation was integrated into a SCRUM projects using a technique known as Remote Synchronous User Testing (RS).

**Diverse development** means that more than three kinds of development were looked at. These studies were majorly by survey and interview methods. For example, SM06, and SM87 investigated adoption of HCI practice in software development companies in two



different countries. Similarly, SM79 using interviews method, investigated adoption of UCD methods in smaller Eastern Finland IT companies. SM73 and SM78 used the survey method to investigate work practice regarding which methods HCI practitioners find most useful in projects and post-deployment usability issue respectively. SM05 used the survey method to investigate process adaptation regarding fitness of UX to scrum/kanban. All these studies indicate the companies were into diverse developments.



**Fig. 6.** Areas of HCI Practice application

Several issues relating to web application development were also addressed. For example, SM03 investigated adoption of UCD and usability among 184 Korean IT practitioners and 90 user interface/usability practitioners and the companies were into web and mobile developments. Similarly, SM13 investigated user feedback incorporation into web application development. SM25, SM33, SM60, and SM76 investigated work practices of usability evaluation in web application, usability engineering support tool for online photo album application, use of HCI knowledge in web application development, and usability and redesign in web application development respectively. SM40 and SM77 investigated integration of UCD principles such as user involvement, rapid prototyping, and continuous testing and effectiveness of usability evaluation methods respectively. SM35 and SM63 examined usability requirements issues such as the link between usability requirements and software architecture, and methods and guidelines to direct users in eliciting usability requirements respectively in the context of web application development. SM69 examined stakeholders' collaboration regarding use of diary study technique to explore the design process of complex engineering systems also in the context of web application development. Other areas of applying HCI practice include game development (SM15, SM44, and SM100), ambient intelligence systems (SM118), assistive technologies (SM90, SM112), and educational software (SM91). SM34 examined integration of usability work into industrial systems projects.

### *5.6. Challenges of HCI practices in software development companies*

We classified the challenges reported by many of the selected studies reviewed into four challenges, namely: performance of projects, expertise, methods, and process. By performance of projects, we mean the actual conduct of usability/UX design, that is those tasks that teams should carry out. Expertise refers to the professionals that carry out project tasks. Methods are HCI principles for conducting work practices. Finally, process is defined as methodological procedures for organizations based on standard design

practices. Table 7 shows the challenges reported. The majority of the problems reported are tied to process, followed by performance of projects and expertise.

**Table 7.**

Challenges of conducting HCI practices in development companies

Performance of projects	Expertise	Method	Process
Quantitative evaluation (SM01)	UCD Knowledge (SM02, SM03, SM33, SM42, SM53)	Practical usability/UCD methods (SM03, SM107)	Development cost and time (SM03, SM59, SM71, SM80)
Heterogeneity of users (SM10)	Trained HCI experts (SM03, SM06, SM10, SM21, SM71, SM86, SM116, SM117, SM132)	Fit for small companies (SM06)	Distinction between customers and users (SM05, SM06)
Usability is fuzzy (SM22, SM31)	Tacit knowledge (SM06)	Integration (SM43, SM45, SM46, SM47, SM75, SM80, SM86, SM121)	Management support (SM09, SM21, SM23, SM31, SM32)
Project vision (SM70)	Awareness of usability methods (SM10, SM31)		Organizational culture (SM29, SM32, SM80, SM86, SM97)
Agile UX (SM70, SM91, SM94, SM103)	Usability engineering tool (SM33)		Difficult to control architecture process like RUP (SM31)
Software documentation (SM71, SM137)	Knowledge of HCI concepts/techniques (SM37, SM105)		Software architecture/design usability (SM107, SM111, SM113, SM120, SM124)
User involvement (SM99, SM111, SM115, SM118)	Knowledge management tool (SM78)		Communication in projects/Stakeholders' collaboration (SM13, SM17, SM23, SM31, SM38, SM57, SM65, SM70, SM71, SM82, SM117, SM 127, SM 134, SM139, SM140)
Late start of UX activities/UX design (SM82, SM123, SM128, SM129, SM130, SM131)	Usability evaluation (SM100, SM101, SM104, SM108, SM109)		Customer's awareness/participation (SM31, SM80, SM135)
			Eliciting requirements (SM21, SM51, SM68, SM106, SM136)
			Usability requirements (SM10, SM35, SM36, SM63, SM67, SM113, SM114, SM126, SM129)
			Training (SM59)
			Leadership (SM81)
			Incorporating user feedback (SM01, SM10, SM11, SM12,

The challenges regarding process are from organizational culture to team communication through to the stakeholders involved in the process. For example, it is reported there is lack of vision due to lack of management support. The roles of users and customers are obscure because there is a lack of clarity regarding who stakeholders are, and what roles they are expected to play? There is poor communication between developers and designers before and during projects. SM09, SM21, SM23, SM31, and SM32 reveal HCI practice is being challenged by lack of management's support. Two studies (SM03, SM108) identified lack of practical usability and UCD methods to support HCI professionals. However, SM09 while admitting the challenge of lack of management's support believe discount usability methods to meet demands of time and resources for usability can help UX professionals cope better. In general, the overarching challenges regarding development process are in terms of software architecture/design usability, communication in large projects, missing usability requirements, and incorporating user feedback.

Nine studies (SM03, SM06, SM10, SM21, SM71, SM86, SM116, SM117, SM132) report there is a challenge of trained HCI experts and although there are few experts; there is still a challenge of lack of HCI knowledge. For this reason, SM21 offered six recommendations for improved usability work in R&D organizations through prioritizing and educating HCI professionals to conduct usability work. There are also few cases of lack of usability engineering and knowledge management tools.

There are some challenges with HCI methods such as their suitability for small companies, adaptability, and integration to software methodologies. For example, human-centred design is not fit for small companies because of lack of resources. Usability is said to be fuzzy during projects and users tend to be heterogeneous. The major challenge regarding performance of projects appear to be late start of UX activities or UX design as a whole.

## **6. Discussion**

Research in the domain of HCI practice in relation to software engineering has emerged and continues to grow. We present detailed discussions of the results in this section.

### ***6.1. RQ1 - How are HCI practice papers distributed over the years and in what venues?***

The results presented in Table 4 show that HCI/SE research papers could be found in multiple sources. However, the results also indicate the prominent digital libraries are:

- Springer;
- ScienceDirect;
- ACM;
- Taylor and Francis, and;
- IEEE Xplore.

These sources include many conference and journal papers. Springer is particularly known for publishing digitized books. Springer among other conference proceedings publishes the following proceedings:

- International Conference on Process Improvement and Capability dEtermination in Software, Systems Engineering and Service Management (SPICE);
- International Conference on Human-Computer Interaction (INTERACT), and;
- International Conference on Human-Centered Software Engineering (HCSE).

ScienceDirect publishes many top journals such as:

- Information and Software Technology;
- Journal of Systems and Software, and;
- International Journal of Human-Computer Studies.

ACM publishes many top conferences in the field of HCI such as:

- Conference on Human Factors in Computing Systems (CHI), and;
- Nordic Conference on Human-Computer Interaction (NordiCHI).

ACM as well publishes conference proceedings in the field of SE such as:

- International Conference on Software Engineering (ICSE), and;
- Human Aspects of Software Engineering (HAoSE).

In addition to this, ACM also archives journals papers in HCI/SE such as the Journal of Usability Studies.

Taylor and Francis publish HCI journals such as:

- International Journal of Human-Computer Interaction, and;
- Human-Computer Interaction.

IEEE publishes conference proceedings of:

- Cooperative and Human Aspects of Software Engineering (CHASE);
- Design and Innovation in Software Engineering (DISE), and;
- Agile Conference (AGILE).

These avenues discuss issues relating to HCI and SE among other issues. Publications are also found in other sources such as IEEE. As can be seen in Figure 2B, there is a higher proportion of conference papers to that of journal papers. Conferences are good avenues for discussing late breaking results and journals and books are excellent for archiving well-established results. Our findings in this study show that 71 papers accounting for 50% of the 142 primary studies were published between 2012 and as at the time of concluding the search in July 2016 (5 years). Furthermore, of the 142 papers, 110 papers were from the academia, while 32 papers were from the industry. Of the 142 papers, there are 10 papers co-written by researchers from academia and industry practitioners based on industry/academia research collaboration. These trends are promising given that many software development companies are recognizing the importance of user consideration in software development processes (Hess, Randall, Pipek, & Wulf, 2013; Rogayah Abd Majid, Noor, Adnan, & Mansor, 2009).

## ***6.2. RQ2 - What types of papers are published in the topic areas and what type of evaluation and contribution do they offer?***

By our classification, HCI practice research topics are centralized on design tools and techniques (25 papers), design methods and contexts (24 papers), design work and organizational culture (22 papers), and collaboration and team communication (14 papers). These topics account for 85 (or 60%) of the 142 primary papers reviewed. Possibly, these topics could be perceived as prevailing topics in HCI practice research with relation to SE processes. However, topics such as Design-driven software architecture (3 papers), Post-deployment activities and software maintenance (2 papers), and cross-cultural design (2 papers) have not received extensive HCI practice research attention. These topics are considered very important especially with increasing effort in Agile UCD integration, and HCI across borders. Cross-cultural design was particularly indicated by SM015 as an area that requires more research focus in order to respond demands being created by emerging markets. Agile approach to elicit user data in order to assist designers to innovate with products and services that do not undermine the cultural issues within the emerging markets was in particular pointed at. For this reason, SM141 proposed a tool for analyzing cross-cultural requirements for designing navigation systems. These topics could be interesting to future researchers. SM077 argued that it is imperative to conduct usability maintenance, that is, understand what happens to the usability of a system after its deployment. The vast majority of the topics are centered on usability engineering, user experience design, and UCD issues.

Our classification scheme has been presented in Table 6. Our own effort was to build a topic facet, which categorizes the primary studies. We have adapted the other two facets as rightly described in Table 6. Evaluation research papers (71 papers or 50% of the total) as can be seen in the systematic map presented in Figure 3, is the largest proportion of the primary studies. This is not surprising because the field of HCI is primarily concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them (Hewett et al., 1996). Figure 3 also revealed that ‘Solution proposal’ (informed by 26 papers) is the second largest in the proportion of research type. Our findings in terms of the proportions of evaluation research and solution proposal are similar to the findings of Mujtaba et al. (2008), which looked at software product line variability. However, there are very few papers in the category of opinion papers (8 papers), validation research (11 papers) and philosophical papers (10 papers). In view of the relative low proportion of these categories of papers, there is a need for more contributions as regard these types of research. For example, validation research could be a follow up effort to a proposed solution, which has yet to be implemented in practice (Wieringa et al., 2006). Philosophical research offers conceptual understanding of issues (Mujtaba et al., 2008). A major concern with the proportion of solution proposal papers to validation papers is that there is a risk of proliferating things. The shortage in conducting validation research could in a way limit the process of transferring research results to practice. This view is corroborated in the study by Wieringa et al. (2006), which note that “validation is weak in software engineering papers” and same could be passed for related disciplines such as HCI. New solutions should be validated within industrial contexts in order to strengthen their rate of adoption in practice. In terms of contribution, method (evident by 61 papers or 43% of the total) is topmost, followed by process (46 papers or 32% of the total).

There is however, just one paper that contributed to metrics. Eighteen papers contribute to tool and 16 papers to model for supporting software engineering works.

If we therefore, map the three dimensions we see that evaluation research is dominant in HCI practice research and topics such as design tools and techniques, design methods and contexts, design work and organizational culture, and collaboration and team communication are prevalent. The majority of these also contribute to methods and processes of software engineering in relation to HCI.

### ***6.3. RQ3 - What research methods have been mostly applied in HCI practice researches?***

It can be seen from the results presented in Figure 4 (A, & B) that the interview method appears to be predominant in HCI practice research. Case study and survey methods are also widely used. However, other relevant methods such as action research, ethnography, and CMD are not as widely used. It has been argued that in order to improve the state-of-art HCI practice research, sometimes as researchers, we need to work from within companies (Ardito et al., 2014; Kotzé, 2002). Action research is suitable for uncovering salient issues in practice and for understanding practitioners' needs and challenges (Gulliksen, Cajander, Sandblad, Eriksson, & Kavathatzopoulos, 2009; Hayes, 2014). Cooperative Method Development is a sub-set of action research and a method of inquiry with practitioners in which researchers and practitioners cooperate to investigate a phenomenon and implement their findings through empirical research (Ardito et al., 2014). As HCI approaches have yet to be adequately addressed in practice, we argue that future researchers could look closely into these underutilized research methods. It is however, interesting to see that researchers used mixed methods in higher proportion when compared to use as single methods of inquiry. Mixed methods research is particularly relevant when aiming to deal with complex issues (Johnson & Onwuegbuzie, 2004). However, relative to software methodologies, it appears there is a growing interest in agile methodologies such as SCRUM, and Extreme Programming (XP). The reason could be due to pressing need for rapid deployments, tight budgets and project deadlines (Mammel, Gundelsweiler, & Reiterer, 2007).

### ***6.4. RQ4 – What HCI techniques have been reported in the current literature regarding HCI practice and in what context of use?***

The results indicated by Figures 5(A-C) suggest that HCI techniques are increasing in adoption in software development companies as well as in projects. The start phase included planning, analysis, and requirement, while the end phase relates to evaluation. In the start phase, techniques such as persona, scenario, interview, contextual inquiry, focus group and survey are being predominantly used. Prototyping appears to be the predominantly used technique in the mid phase, while heuristic evaluation, think aloud, expert review, and cognitive walkthrough are used techniques in the end phase.

From the reviewed papers, it was found that the use of the afore-mentioned techniques has also been largely promoted by the introduction of ISO standards for human-centred developments such as ISO 13407 (ISO, 1999), which was later developed into ISO 9241-210 (ISO, 2010). ISO 9241-210 is a framework, which specifies 6 principles for human-centred development. The 6 principles are:

- i. Explicit understanding of users, tasks, and environments;

- ii. Involvement of users throughout design and development phases;
- iii. Design of the system is driven and refined by user-centred evaluation;
- iv. Design of the system is iterative;
- v. Design of the system addresses whole user experience, and;
- vi. Multidisciplinary skills and perspectives are applied to the design process.

Researchers found iterative design as a strong commonality between the human-centred design principles and agile principles. Therefore, there have been several efforts to integrate human-centred design and agile methodologies. SM91 advocated for Agile UXD for inclusive educational software design where they argued that UCD puts the user at the heart of design contrary to agile methodologies, which put the developer and the customer at the center. In particular, the authors noted that UCD describes “a prototype-driven software development process, where the user is integrated during the design and development process” (p.150). A similar remark was made by SM96 for serious game development, SM131 for UX development for collaborative mobile prototyping and SM43 for integrating UCD to agile processes. Nevertheless SM115 outlines 4 challenges found with implementing UCD, namely: (1) Acceptance, recognition and incorporation of the User-Centred Design practice, (2) Lack of resources, (3) Changes in the projects definition, and (4) Management of multidisciplinary team. Similarly, SM30 while exploring familiarity of usability methods among map application developers argued that it is not always straightforward to integrate methods emanating from different research domains to other application areas. One reason presented by the authors is lack of knowledge required for integration. SM79 found that adoption of UCD methods is low in smaller companies in Eastern Finland. SM88 found that the impact of the professional–client relationship is a key factor that hinders user involvement in the context of designing mobile systems by UCD practitioners.

Other records of applying HCI techniques include the work of SM111, which explored optimization of persona and scenario in the design and evaluation of usability and accessibility of Ambient Assisted Living (AAL) systems and services. Personas and scenarios were found beneficial to addressing the difficulty of communication experienced among stakeholders (users, care givers, developers) involved in the development of AAL systems and services. However, SM62 found that in practice, personas might not be used as described in the literature; rather practitioners create personas based on the real users and only employ the technique when they feel comfortable to do so. The rationale for creating personas based on the real users is that if the wrong user group is described in personas it could lead to developing wrong software solutions. This finding could be interesting for future researchers. The study also revealed that practitioners perceive scenarios relevant based on its similarity with user stories. Personas have also been proposed as a conjoined technique that could be used with Generic User Experience Model (MEX) Experience Boards to uncover hidden UX issues by SM103. Similarly, SM105 in their study modified personas into a technique that can be used to elicit software requirements. SM124 shared their experience of integrating personas into Extreme Programming/UCD process. According to this study, personas were created in two stages; in the initial stage based on existing user studies and in later stage based on new studies. Personas had to be iteratively refactored due to visible changes emanating from the new studies. Therefore, it was concluded in the study that



personas should be well introduced to the team to foster planning and development of the solution and decision-making process.

SM75 in a survey of practitioners' adoption of UCD found that user interview and prototyping (low and high fidelity) were the mostly used techniques. SM91 found that prototyping and heuristic evaluation were useful, fast, and efficient techniques in the design and evaluation of inclusive education software for children with certain learning difficulty. Similarly, SM100 found prototyping as a useful technique in early pervasive game development. Paper prototyping when used to create detailed screen layouts, and software prototyping techniques were found to be effective but time-consuming. The reasons for time-consumption are complexity of game application and detailed prototyping. Nevertheless, early prototyping was found valuable. SM93 reported that prototyping, and usability testing, were adopted by a company moving from waterfall process to Agile UCD. Lightweight prototyping were used in the study by SM124. SM125 in harnessing the benefit of prototyping technique, proposed POLVO software that has the functionalities to create low-fidelity prototypes, document, and support user testing to facilitate interface development in SCRUM process. SM131 developed a mobile prototyping tool (Prime) to facilitate elicitation of hedonic issues in user requirements by focusing users' tasks in context of use. From the foregoing, we can understand that HCI techniques have varying benefits and the known challenges should be looked into.

#### ***6.5. RQ5 – In what development project areas has HCI practice been applied as documented in the existing literature?***

As can be seen in Figure 6 HCI practice cuts across a wide variety of interactive systems development. The analysis of the results reveals that similar issues are associated with the different areas or development focuses where HCI practices are being applied. The common areas where HCI practices are being conducted include product development, especially commercial software, web application, mobile application, information/management systems, and game development. Others include industrial systems, educational software, and assistive technologies. It can be understood that advances in web and mobile technologies might be responsible for companies to conduct HCI practices. However, SM35, and SM112 stressed that web application developments are complex systems. For example, SM35 examined the impact of usability on web systems. In particular, the study investigated the link between usability requirements and software architecture by examining five scenarios in which usability problems can be found. The study found that supporting international use has a major usability impact on web application architecture. Other results include checking for correctness (intermediate impact), providing good help (minor impact), modifying interfaces (minor impact), while retrieving forgotten passwords has no usability impact on web application architecture. Regarding interfaces, SM60 argued that many web application interfaces are still difficult and annoying to use. Frustration usually arises from inefficiency of web application. In the same vein, SM112 noted that usability requirements are often missing in quality requirements of web applications and proposed a requirement metamodel for eliciting requirements in web application projects such as web information systems. The metamodel seeks to capture usability issues by conducting early usability evaluation.

Mobile application development is said to have a unique challenge of short time to market according to SM74. For this reason, the authors explored use of usability techniques and the effect of such endeavor on user interface design of a mobile application development project. The study reported the useful benefits of conducting usability testing during the project. SM131 developed a mobile prototyping tool to aid users' tasks in their context of use. Particular focus of the tool is on revealing hedonic parameters in design process through mobile prototyping.

SM91 described an education software development project in which inclusiveness of the software was prioritized in the design process. The software was intended for children with Downs's syndrome – a learning difficulty. The goal was to identify usability problems and UX factors in the early stages of developing educational software for users with special educational needs. Similarly, SM90 stressed end users engagement in assistive technologies development is a major challenge. This is especially found true of people with severe disabilities such as adults with Severe Speech and Physical Impairments (SSPI). In particular their involvement in projects is problematic. A solution adopted by the study was the inclusion of user advocates in agile UCD process. Overall, it can be concluded that areas of applying HCI practices in development projects is inexhaustible. It depends on the project at hand and whether the intention is to build interactive systems for specified users and in specified contexts of use.

#### ***6.6. RQ6 – What challenges have been reported in software development companies regarding HCI practices?***

Focusing on the challenges presented in Table 7, one could see the overarching issues are personalities involved with development processes. **User feedback** incorporation is one of the main **usability evaluation** issues in companies. It would be recalled that one of the principles of human-centred design is design driven by user-centred evaluation. This implies that a lot of feedback can be collected from users and other stakeholders during the design process. Therefore, in attempting to integrate UCD to agile processes, challenges arise due to rapid communication with different stakeholders to elicit feedback and implement feedback within design iterations. For example, it could be overwhelming for the project team to determine at what point should enough feedback have been elicited and whether all feedback should be incorporated. Feedback from user is mostly based on usability and user experience of using the system. For example, SM01 hinted that it is challenging to incorporate user feedback in Scrum process due to rapid releases of working software and exquisite stakeholders' communication. Informal feedback are managed to be collected from very few users and performance measurements are hardly done. In response to the kind of challenge reported by SM01, an approach used by another study (SM09) was to combine 2 discounted usability methods into a single method called Rapid Iterative Test and Evaluation Method (RITE) and Stephen Krug's Usability Testing (Krug), that is, RITE+Krug. The results of SM09 where the combined method was used revealed that tests take only few hours of the stakeholders' time and feedback were quickly received and implemented. However, the new method still needs to be used in more industrial project settings. Talking about industrial settings, SM023 believe organisational conflict, breakdowns, and barriers in terms of usability work can be resolved by "developing the right product (that) requires communication and collaboration between multiple stakeholders." Furthermore, it is important to include end users, based on the fact they have a holistic understanding of their work context. Further

on informal feedback, SM048 found that although informal feedback is to determine context of use and suggest design approach, users' responsibilities are not clear in Scrum projects. SM055, however, found that usability evaluation could be effectively integrated in Scrum projects through the use of Remote Synchronous User Testing. This kind of approach gives room for timely feedback to be incorporated into the development process. The main challenge is that developers have to be flexible in switching between the traditional face-to-face usability evaluation and remote usability testing.

**Contextual issues.** Studies SM06, and SM10 reported some contextual challenges for usability works in developing countries. Mentions were made of software development companies in Nigeria (SM06) and Ethiopia (SM10). Specific mentions were made of heterogeneity of users, developers' lack of familiarity with usability methods. These issues appear not to be limited to developing countries. SM66 reported that usability and UX design work in Scrum process is challenging due to limited resources available to development companies and a sheer lack of priority for usability and UX works. A similar study conducted in Denmark (SM07) reported the challenge of shortage of professionals to conduct UX work activities. Furthermore on **user feedback**, although SM11 reported that users show low motivation at providing feedback and have preference for what is ready for use, this is not necessarily always true and the idea is to promote user ownership of the design. Developers also struggle to understand the contextual information necessary for the systems they are developing when users are reluctant to provide feedback. SM12 reported that user feedback get lost in collocated agile teams, especially between support and product teams. SM16 also reported that capturing and measuring UX feedback is challenging.

In trying to resolve these challenges, an approach reported by study SM10 was to use prototyping technique to get early feedback from users. Similarly, software developers were trained to conduct A/B usability testing in the study by SM07. In SM66, developers were also trained to conduct UX tasks in line with the Scrum principle, which stipulates that team members should be able to perform every work task in projects. Another approach used in another study (SM93) to address the difficulty of incorporating user feedback in agile process, was to include little design upfront (0 Sprint), do lightweight documentation, and conduct parallel tasks. Startups might, all the same, have unique challenges. An approach used by SM11 to address this problem was to develop and evaluate a context-aware feedback system (CAFE). This system is capable of collecting in-situ user feedback and integrates them in a timely manner. The results from the study indicate that users feel more confident to share their feedback while working and as a result, their involvements in projects improve. An approach explored by SM16 was to use self-reporting as a technique to capture users' emotions and results obtained were positive. SM142 described taxonomy of methods that can be used for conducting human-centred design studies as well presented few instances of systems developments where the methods can be applied. SM24 developed and assessed two metrics for determining the effectiveness of integrating HCI activities to software engineering processes. In relation to getting in-situ users' feedback, an approach proposed by SM28 was the cooperative usability testing method. The results of SM28 show that this kind of evaluation gives access to testers work-domain knowledge and experiences as users. Nevertheless, SM88 argued that UX design needs and practices in start-ups are not well understood. A critical question raised was how could start-ups do UX design with little

resources? An approach used by start-ups for collecting user feedback is by seeking professional advice through personal networks. Start-ups feel they need to collect data from actual usage and user analytics to improve their UX design practice.

**Capturing and including usability requirements** are another challenge regarding HCI practice. SM10 in their study conducted in Ethiopia revealed that usability has yet to be promoted either in practice or at policy level. Furthermore feedback is not collected from actual users but “IT supporters” who used the software on behalf of actual users. For this reason, SM10 suggest the use of personas to address the challenge of designing for heterogeneous user groups. Authors believe personas can be used to capture usability requirements from users in their context of use. Similarly, SM35 while addressing the link between architectural decisions and usability requirements, proposed scenarios can be used to sort usability issues in software architecture design. SM113 reiterated the fact that usability issues have a real impact on software design. For this reason, SM63 proposed a method - Quality Attribute Workshop (QAW) to support development companies in discovering and documenting usability requirements for successful software architecture design. SM67 proposed a method called UserX Story. UserX Story is an adaptation of user story and user experience. Authors believe such an approach can be employed to mitigate the challenges encountered by development teams to incorporate UX aspects and usability requirements. Similarly, SM129 supported incorporating usability recommendations into user stories. The reason is that usability as critical quality factor can be integrated into user stories, which happens to be a de-facto artifact for communicating agile requirements.

**Communication in project teams and stakeholders’ collaboration** are other aspects where there are challenges in development companies. SM13 revealed a challenge of moving design ahead of development under short time frame in agile processes such as SCRUM. SM93 had in 2007 proposed a method that allows design to be one sprint ahead of coding. SM93 indicated this approach helped to reduce the gap between finding usability problems and acting on those problems by incorporating timely changes into the product. SM134 later in 2016 argued that the within-iteration is a better approach to improve communication between UX specialist and agile developers. The author reveals that the iteration-ahead approach could easily become a mini waterfall process. Furthermore, feedback loop can grow considerably and make change implementation slower and more difficult. For this reason, SM134 proposed a framework – Best of Both Worlds (BoB), which is built on the within-iteration approach and seeks to integrate UX work in agile development better. In their own work, SM13 proposed design studio – a rapid process that allows designers, developers, and other stakeholders to collaborate and explore design alternatives. SM17 and SM38 were concerned about who has the authority to speak in the design process. SM38 argued that quality of interactive software is incomplete without including usability and UX professionals require more explicit role in agile projects and more authority. For this reason, the authors propose UX professionals to have the authority to discard suggestions that end users perceive as not useful. SM17 believe design methods as discourse on practice need more exploration. SM23 argue that development of successful products requires communication and collaboration between multiple stakeholders. Furthermore, end users should be part of this collaboration since end users fully understand their work environment. Authors revealed that there has to be organization and process change in order to achieve this collaboration. User centred

design is a way to achieve this change. In their work, SM57 reveal that task allocation between UX professional and developers is a major challenge in agile projects especially in enterprise systems development and suggest a task-oriented approach for projects with minimal UX resources. Similarly, SM82 reiterate the roles of UX professionals are not well defined in project teams. SM65 reveal that the work setting in which professionals and agile developers work together and collaborate is unclear. Similarly, SM139 reiterate the course of collaboration is also unclear. For this reasons, SM65 suggest explicating contextual values in order to improve work setting and SM139 proposed a cross-discipline user interface design lifecycle. SM117 demonstrated that user interface transition diagram (UITD) – a modeling notation can be used to improve communication between stakeholders in software development projects. In the same vein SM127 proposed Ripple – a framework for usability engineers and developers co-existing in cooperative and complementary roles.

From the foregoing, it can be seen that one of the major challenges in conducting usability and UX works in development companies is how to effectively collect user feedback in timely manner and integrate them in development process. It is promising to see that some approaches such as remote usability testing, cooperative usability testing, context-aware feedback system, etc. have been proposed and applied. However, it is still unclear whether the challenges of collecting and integrating user feedback are more prominent in agile processes than other processes. Furthermore, what challenges do users' pose aside their heterogeneity? Are existing approaches sufficient enough for all contexts? What discount usability and UX methods are promising for start-ups and Small to Medium Enterprises (SMEs)? There are many pressing challenges as can be seen from Table 7. The challenges seem inexhaustible. Overall, communication in teams and collaboration among stakeholders, capturing and including usability requirements, and incorporating user feedback appear to be more pressing.

### ***6.7. Threats to validity***

The major threats to the validity of this study are identifying relevant publications, and data extraction and classification. There are discussed in turn.

#### ***6.7.1. Identifying relevant publications***

It is not possible to include all studies published in the period covered in this study. Basically, this study was guided by its inclusion and exclusion criteria. It is possible that some papers were automatically excluded due to the scope of the study and the search string. Some potential studies were written in languages other than English and automatically excluded. Some relevant studies were published after the conclusion of the literature search and not included. It is also possible that areas where we have witnessed low level of publication have been published in other sources. Further, we rely only on finding relevant papers through searching on the digital libraries listed in Table 4 and by manually searching some conference proceedings available to us. However, we feel confident that the sources where our search has been conducted enhanced the reliability of our results. These sources publish most of the research papers in HCI practice in relation to software engineering processes. Furthermore, we examined previous similar studies and are confident we have explored the relevant sources.

#### ***6.7.2. Data extraction and classification***

The most challenging aspect of data extraction and classification process is classifying the primary studies by topic because of the intricate nature of HCI/software engineering papers. This implies there could be some level of subjectivity with classifying papers by topic. Thus, it is possible that if the study is repeated there could be some degree of variation with the topics. It is a commonly known fact that classification of papers is not mutually exclusive (Ivarsson & Gorschek, 2009). In order to mitigate this situation, paper abstracts, introduction, discussion, and conclusions were read iteratively and classified by topic, and this was discussed among the researchers and refined. We also mitigate this risk by utilizing the third researcher as an internal reviewer and the fourth author as an external reviewer. On the other hand, the classifications by research type and contributions were adapted from Wieringa et al. (2006) and Mujtaba et al. (2008) respectively. This gives us some confidence regarding the level of reliability of our study classification.

### ***6.8. Implications for research and practice***

For researchers, various issues such as adaption of HCI techniques to context, integration of usability requirement in software architecture design, incorporating user feedback in Agile UCD, among others present some opportunities for future research. As efforts are geared towards proposing solutions that could be deployed in practice, there is a need to validate these proposals. Some topics such as cross-cultural design, post-deployment activities and software maintenance, and domain and knowledge have also received little attention and they need to be considered by future research. There is sparse consideration for research on metrics. Metrics are important measurement standards or functions for determining whether a software system has certain properties or meets certain design thresholds. There appears to be a lack of focus on how HCI concepts are being implemented in design of software systems. HCI researchers could also be interested to know why HCI research results are used or not used in industry.

For practitioners, the major problem with software development process is that sometimes when products are deployed for use, they are still found unusable and not meeting certain human values such as accessibility support, identity, inclusiveness, and so on. The reason in many cases is usually due to neglect of human considerations and values. Practitioners can avail themselves of the opportunities HCI practice research papers provide. Practitioners can also take advantage of the findings of this study, especially solutions proposed to mitigate some known challenges discussed in section 6.6. For example, practitioners could benefit from using the various techniques and methods presented in Figure 5 (A-C) at appropriate stages of their development processes.

## **7. Conclusions**

HCI practice research has emerged slowly and steadily beginning from the studies of Nielsen, Norman and Draper, and Winograd. However, there still appears to be a lack of coordination in HCI practices of how techniques or methods are being applied to the software development processes and what challenges are being experienced and there is a need for a systematic mapping study to produce a map outlining the HCI practice research landscape. Six questions were raised and mapped with specific goals to identify existing studies on HCI practice and structure them in such a way that outlines the HCI practice research landscape and what challenges are prevailing in companies. This study

analyzed 142 primary studies, identified from 2384 papers initially found through automatic search of digital libraries and an additional 43 papers found manually. Our systematic map presents state-of-the-art HCI practice research in relation to software development since 2000. The overarching goal was to provide an overview of research topics, determine the methods and type of research and available results.

HCI practice research has emerged more prominently since 2012. Conference papers represented by 58% formed the bulk of the 142 papers reviewed. Evaluation research seems dominant in HCI practice research and topics such as design tools and techniques, design methods and contexts, design work and organizational culture, and collaboration and team communication are prevalent. The majority of these also contributed to methods and processes of software engineering in relation to HCI. There were more studies, which used mixed methods than single use, and this is promising for HCI practice research because of the complex nature of software development practice. The interview method appears to be predominant in HCI practice research. Case study and survey methods are also widely used. HCI techniques appear to be increasing in adoption in software development companies as well as in projects. Techniques such as persona, scenario, interview, contextual inquiry, focus group and survey are being predominantly used in the planning, analysis, and requirement phase. Prototyping appears to be the predominantly used technique in the mid phase, while heuristic evaluation, think aloud, expert review, and cognitive walkthrough are used in the end phase. Overall, it appears more HCI techniques are used in the start phase compare to the mid and end phases. HCI practice cuts across a wide variety of interactive systems development and has been adopted in the development of web and mobile applications, information/management systems as well as assistive technologies.

There are a couple of issues regarding user feedback, usability requirement, process adaption, and stakeholders' collaboration among others and these create some challenges. The challenges presented in Table 7 provide some opportunities for future research. For example, it could be interesting to know how knowledge is created and shared in teams. How is knowledge created and shared in on-site, off-site, and geographically dispersed teams? What kind of knowledge is created and shared in various categories of team? Does knowledge sharing foster team communication and to what extent?

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